Parameterizing the Energy Cascade from Large Scale to Mixing
AESOP: Ocean Physics Group Progress Report

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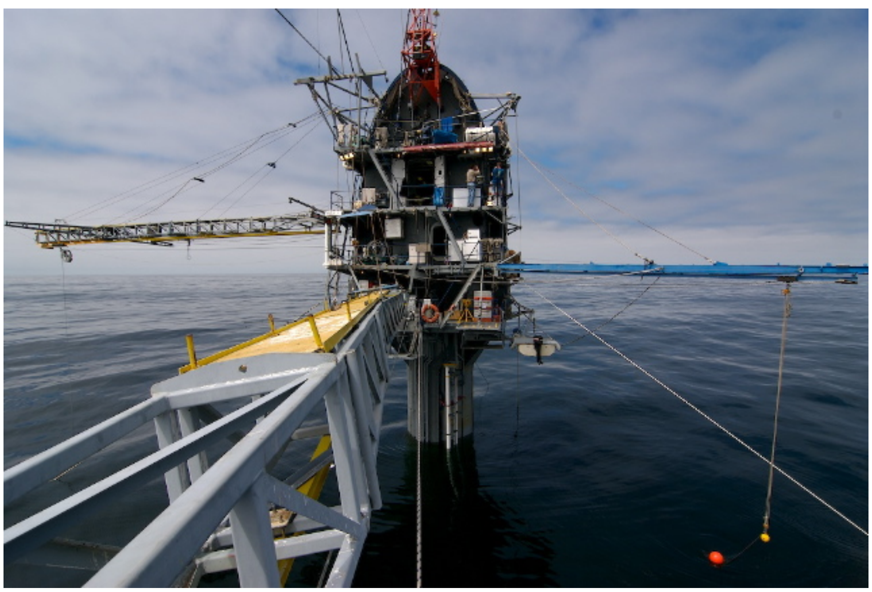

Figure 1: **R/P FLIP** *deployed on the south of Monterey Bay during AESOP. The port boom, on the left, supported the Deep 8 Doppler system; the aft boom, in the foreground, supported the fastCTD.* **(Photos: T. Hughen)**

LONG-TERM GOALS

Our long-term goal is to understand how energy is supplied to the ocean, and how it subsequently cascades to the turbulence and mixing important to the circulation, and the transport and distribution of tracers. This problem involves scales spanning subinertial motions to turbulence, and therefore requires

integrative efforts with other sea-going investigators and numerical modelers. AESOP was an excellent opportunity to collect a data set in the coastal environment to test our understanding of the cascade.

OBJECTIVES

To test if high resolution models (i.e. SUNTANS, K. Winter's model) generate realistic internal waves due to tidal and wind forcing.
To see if these models move energy from the large to the small scales properly.
To test how well Mellor-Yamada/KPP parameterizations do at estimating the location and magnitude of internal wave-driven mixing in these high resolution models.
To determine if the differences between observed and modeled mixing matter for quantities of operational and oceanographic relevance.

APPROACH

Progress is achieved through a cycle of instrument development, field observation, data analysis and comparison with theory and models. The primary instruments employed include Doppler sonar and rapidly profiling CTD's. Our instruments produce information that is quasi-continuous in space and time, typically spanning two decades in the wave number domain. This broad band space-time coverage enables the investigation of multi-scale interactions.

WORK COMPLETED

We deployed from *R/P FLIP* in Aug/Sep 2006 (figure 1). We moored in approximately 920 m of water at 36 29.7480N,122 5.6450W, with anchors at the locations given in (table 1) and pictured in figure 2. We had planned to be slightly west of this point, but were pushed east by unexpected currents.

Table 1: FLIP location and anchor drop locations. Each anchor was on 1829-m lines in 1000 m of water, so the anchors are closer to* R/P FLIP *than the drop positions indicate.

	Lat 36° N	Lon 122° W
R/P FLIP	29.748′	5.645′
Keel Anchor	30.767′	5.717′
Port Anchor	28.921′	6.454
Stbd Anchor	29.496′	4.287

Cruise preparations included modifying the fastCTD for use aboard *R/P FLIP* (figure 3) and substantial work to refurbish the Deep 8 sonar system. The sonar system was deployed from the port boom (left hand boom figure 1) at a depth of 415 m. The CTD was deployed from the aft boom (in the foreground of figure 1) profiling between the sea surface and floor.

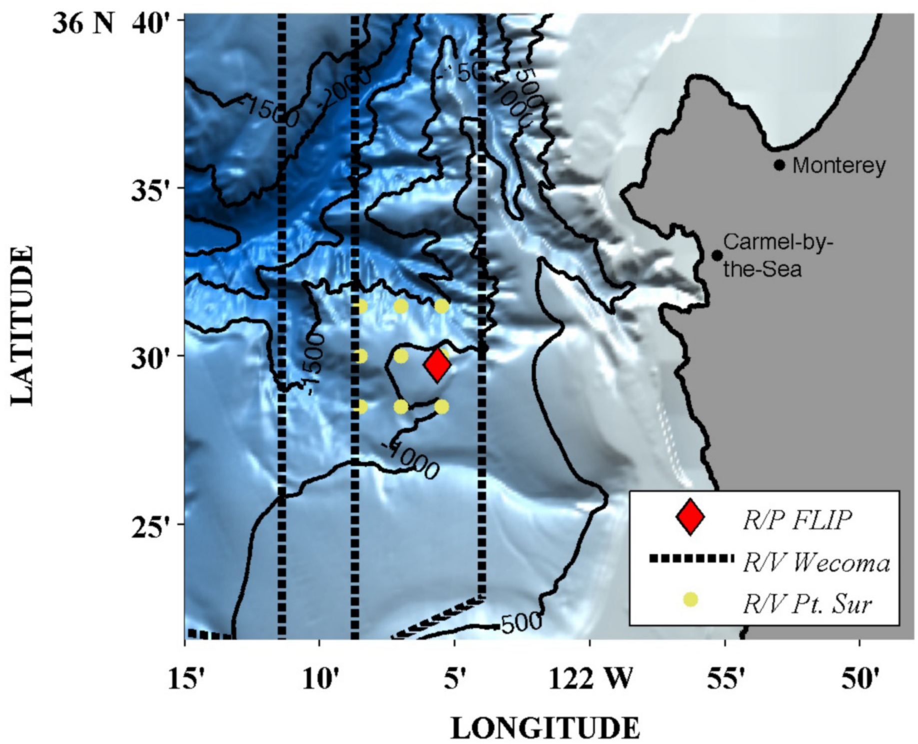

Figure 2: Location of FLIP in the context of the off-shore internal wave part of AESOP experiment. Dashed lines are SeaSoar tracks made by Johnston and Rudnick, yellow dots are XCP surveys by Girton and Kunze.

RESULTS

An example of the high resolution data set collected with the instruments deployed aboard *R/P FLIP* is shown in figure 4. The tide is clearly seen in the measurements both as alternating bands and as heaving in the isopycnals. Note how the lines of constant shear (shaded) follow the contoured isopycnals.

We have begun to use these measurements to characterize the wavefield in a number of ways. First, the observed energy flux at the site is relatively weak, and has an apparent spring-neap cycle (figure 5). The average number for the whole tidal cycle is $0.26\,\mathrm{kW\,m^{-1}}$ to the north and less than that to the east. Comparisons will be made to the energy fluxes in SUNTANS for similar forcing. Our measurements agree with Girton and Kunze's for the early part of our cruise when the tidal forcing was most similar.

We have also made progress in characterizing the turbulence and internal wave characteristics. Energy density ($KE = 0.5(u^2+v^2)$ and $PE = 0.5(N^2\zeta^2)$) does not follow a clear spring-neap cycle, but rather appears to pick up during neap tide, particularly at mid depths (figure 6).

We have compared the dissipation rates observed using overturning scales and those estimated from the internal wave continuum energy levels using the Gregg-Henyey proxy (figure 7). The correspondence between the two is poor, particularly deeper than 400 m. Part of our efforts will be based on trying to improve these parameterizations, since their applicability appears limited except in the open ocean.

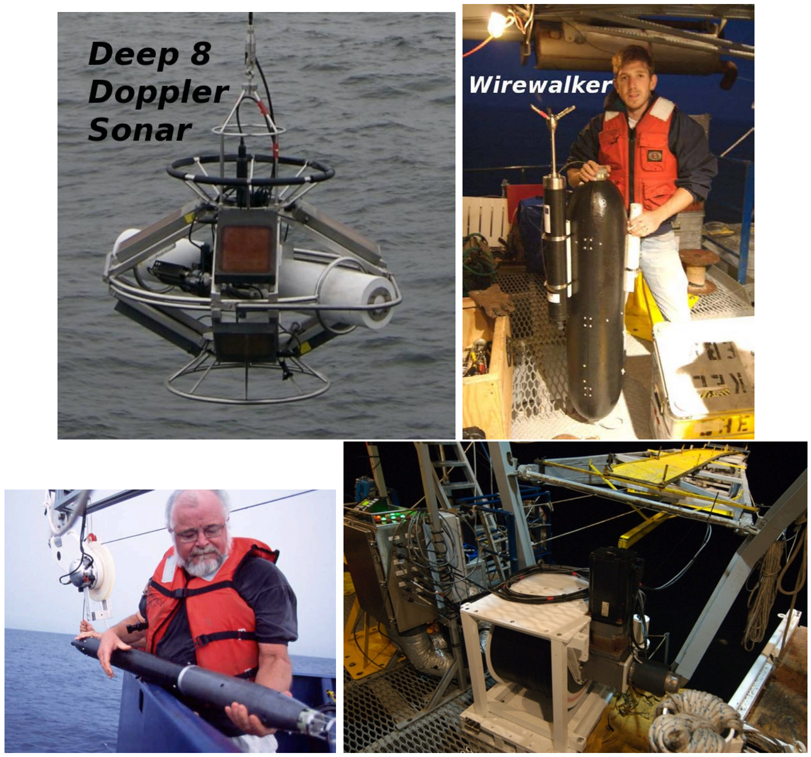

Figure 3: Instruments deployed as part of the AESOP experiment. Clockwise from upper left: the Deep 8 Doppler sonar, the wirewalker, the CTD from the fastCTD, and the winch system for the fastCTD.

IMPACT/APPLICATIONS

Understanding the source of turbulence in the ocean is a primary goal of ours. If we are successful, our understanding will lead to improved parameterizations for turbulence and mixing, which can be used in regional models.

RELATED PROJECTS

This data set is an important part of the AESOP effort, and we will be working closely with the other AESOP PIs to interpret and integrate it as described above.

This work is complementary to the work carried out in the Hawaiian Ocean Mixing Experiment, and we have already started comparisons with that data set. Similarly, ideas about the nature of the internal wave field that Pinkel developed for data collected as part of the Surface Heat Budget of the Arctic Ocean (SHEBA) experiment will be tested with this data.

Finally, it is complementary to Klymak's work at UVic, funded through the Canadian National Science and Engineering Research Council, to look at coastal internal wave processes.

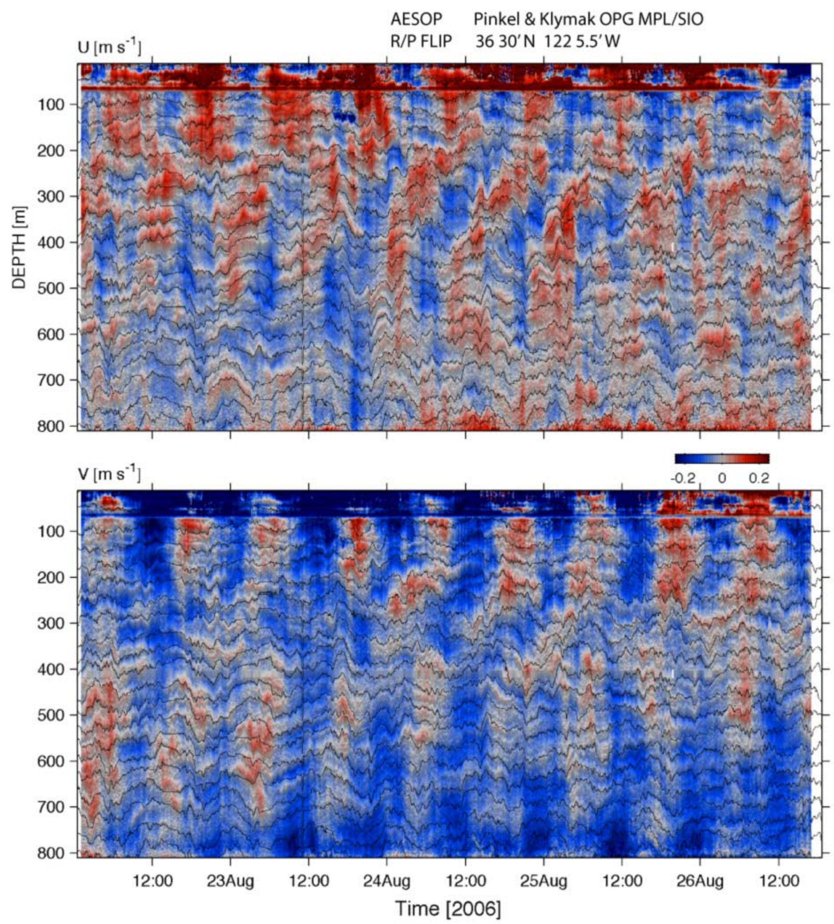

Figure 4: Velocity and density for 5 days during the cruise. Rapid sampling of the density helps deconvolve advection of velocity layers by displacements using the semi-Lagrange transform.

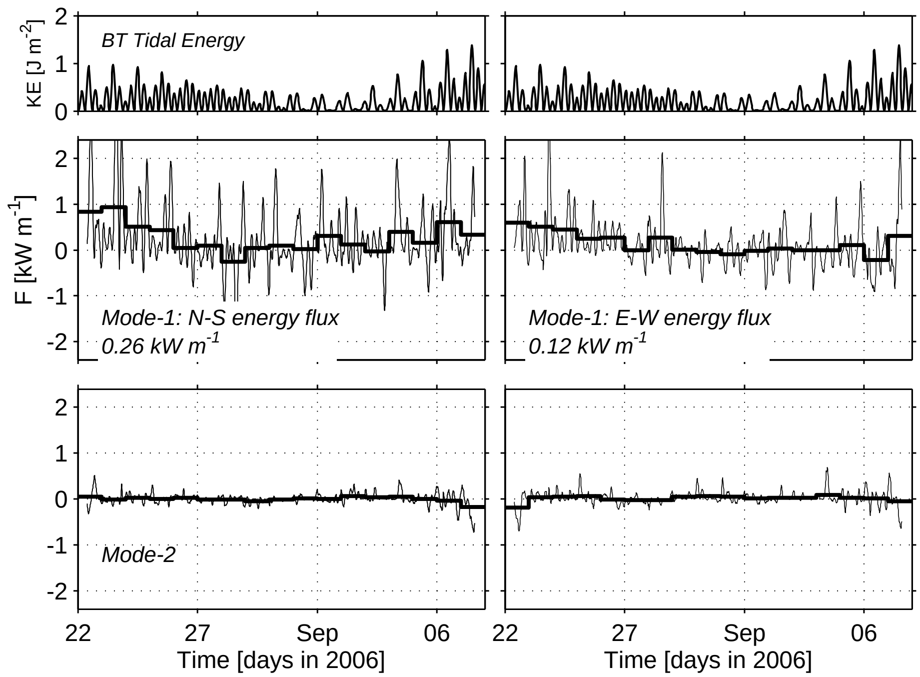

Figure 5: Energy flux at the FLIP site for modes 1 and 2. Thick line is 1-day averages of the energy flux. No harmonic fits have been performed for these estimates.

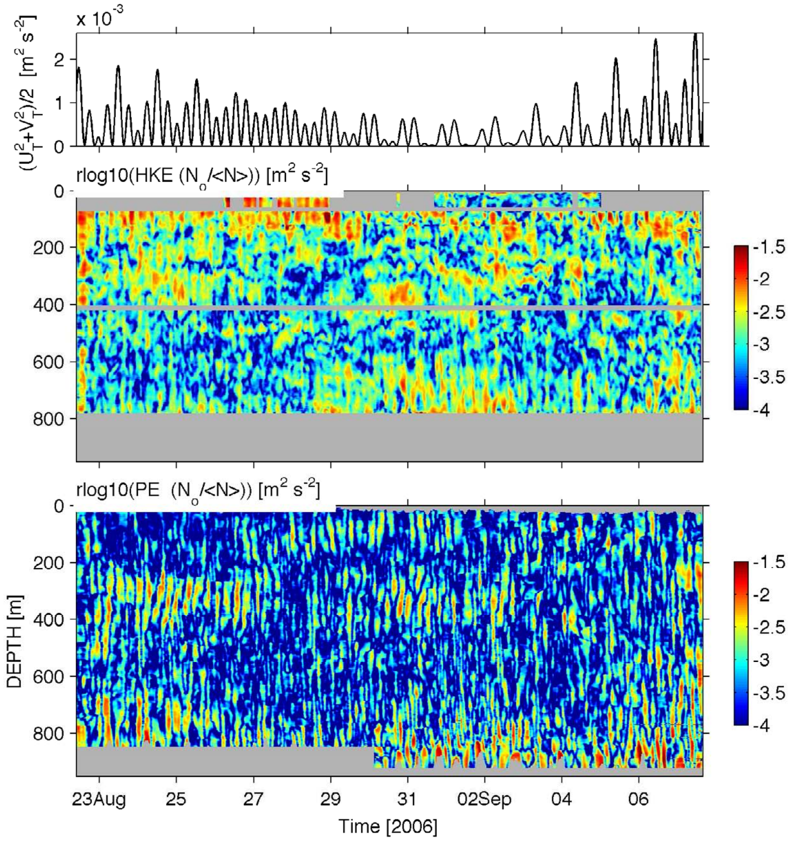

Figure 6: Energy (KE and PE) observed at the **R/P FLIP** *site.*

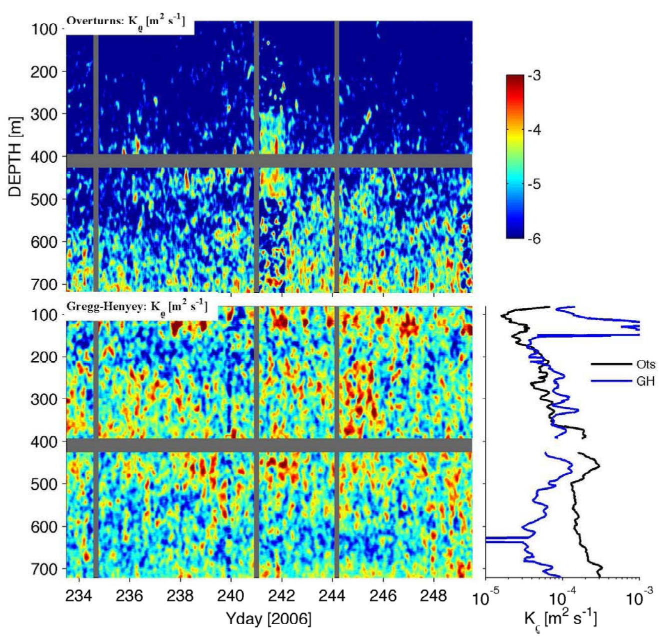

Figure 7: Turbulence dissipation rate estimated at **R/P FLIP** *using overturns (upper) and the Gregg-Henyey method (lower).*